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Reply to comment on "Coronal mass ejections, interplanetary ejecta and geomagnetic storms" by Gopalswamy et al.

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[1] The comment of *Gopalswamy et al.* [2003] relates to a letter discussing coronal mass ejections (CMEs), interplanetary ejecta and geomagnetic storms [*Cane et al.*, 2000]. *Gopalswamy et al.* [2003] contend that Cane et al. incorrectly identified ejecta (interplanetary CMEs) and hypothesize that this is because Cane et al. fail to understand how to separate ejecta from "shock sheaths" when interpreting solar wind and energetic particle data sets. They (*Gopalswamy et al.* [2003]) are wrong because the paper was concerned with the propagation time to 1 AU of any potentially geoeffective structures caused by CMEs, i.e., upstream compression regions with or without shocks, or ejecta. In other words, the travel times used by Cane et al. were purposefully and deliberately distinct from ejecta travel times (except for those slow ejecta, ~12% of their events, which generated no upstream features), and no error in identification was involved. The confusion of *Gopalswamy et al.* [2003] stems from the description of Figure 3 of the paper which, we acknowledge, did not characterize the observations sufficiently clearly.

[2] Figure 3 of *Cane et al.* [2000], as stated in the figure caption, shows the transit times of solar wind "disturbances" associated with CMEs observed by LASCO. The disturbance travel time is that of the shock or upstream wave-like feature if present, or that of the ejecta if the ejecta speed is sufficiently slow that there is no upstream feature. In 74% of the events, the disturbance time corresponds to the passage of a shock. Thus, Figure 3 does indeed show a "mixed-bag" of event types, as *Gopalswamy et al.* [2003] conclude. It does not show (and was not intended to depict) ejecta travel times.

[3] We chose to show disturbance travel times because: (a) they are more relevant to the onset of CME-related effects at Earth than ejecta travel times; (b) the disturbance arrival time is usually well defined whereas the time of ejecta leading edge passage is often difficult to determine precisely, and (c) though less of an issue for the current solar cycle, the shock arrival time is easily established (from the geomagnetic storm sudden commencement) for events where there are limited solar wind observations, and the disturbance therefore provides a consistent event time for extended studies of solar wind transients [e.g., *Cane et al.*, 1994].

[4] On re-reading the paper, we agree that we neglected to draw attention to this point sufficiently clearly in the text. We stated that "Figure 3 shows the 1 AU transit times for the events of our study". Without referring to the figure caption, and lacking a clear definition of the *disturbance* transit time, the reader might reasonably assume that "transit times for the events" refers to those for ejecta, in particular since the related section of the paper is entitled "Transit times of ejecta". We then compounded this oversight by using "ejecta" instead of "disturbance" on two occasions in the subsequent text, as well as in the abstract. Thus we can certainly understand why *Gopalswamy et al.* [2003] find our comments in relation to Figure 3 confusing. The point that we intended to make is that the ejecta arrival time prediction model of *Gopalswamy et al.* [2000] is not particularly useful in predicting disturbance arrival times, which tend to be earlier than the times predicted by the *Gopalswamy et al.* [2000] model (see Figure 2(a) of *Gopalswamy et al.* [2003]). There seems to be no disagreement between *Gopalswamy et al.* [2003] and ourselves on this issue.

[5] To illustrate how ejecta transit times for the events in the *Cane et al.* [2000] study compare with the *Gopalswamy et al.* [2000] model, Figure 1 shows ejecta transit times plotted vs LASCO CME speed, together with the model curve giving the predicted ejecta transit times. (Note that there are three extra events that were omitted from Figure 3 of *Cane et al.* [2000] because a lack of solar wind data excluded them from other aspects of that study.) Figure 1 shows that there are approximately equal numbers of ejecta that arrive ahead of the time predicted by the *Gopalswamy et al.* [2000] model relative to the number that arrive on time, or late (this is to be expected since the model itself is based on a fit to similar observations). Thus our statement that "the majority of ejecta in our study arrive earlier than predicted" is incorrect, as pointed out by *Gopalswamy et al.* [2003] - we should have said "the majority of disturbances". Nonetheless, in view of the scatter still remaining even when ejecta transit times are considered, we stand by our general comment that an empirical formula for (disturbance or ejecta) transit times based on CME speed is not particularly reliable for prediction purposes. The large scatter in ejecta arrival times in Figure 1, which can differ

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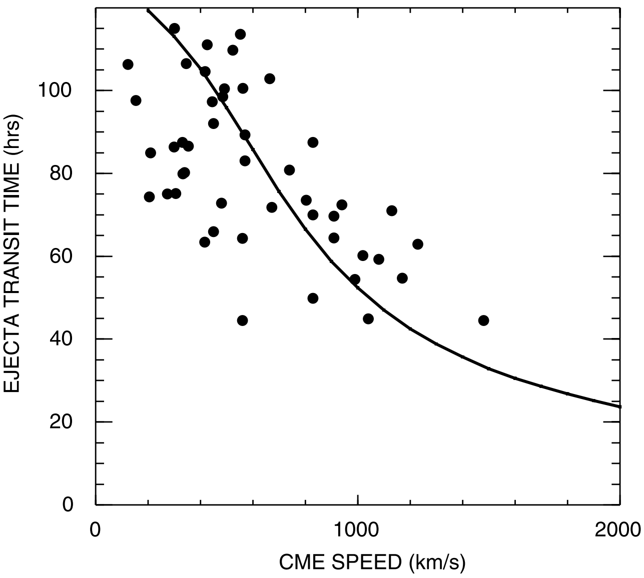

Figure 1. Ejecta transit times versus the speeds of associated CMEs observed by LASCO, for the events in *Cane et al.* [2000]. The curve is the prediction from the *Gopalswamy et al.* [2000] model.

by up to ~40 hours for similar CME speeds also seems to be at odds with the claim of *Gopalswamy et al.* [2003] that ejecta arrival times can be predicted to "within ±10.7 hours".

[6] We also do not fully agree with conclusion (iii) of *Gopalswamy et al.* [2003] that "one has to separate the ejecta and shock travel times before assessing the extent of scatter in the observed transit times". If one is interested simply in the transit time of any CME-related effect in the solar wind, which is most relevant for space weather forecasting, then such a separation is unnecessary.

[7] It is also arguable that the ESA model of *Gopalswamy et al.* [2003] orders the shock transit times in Figures 2(b) and 2(c) of *Gopalswamy et al.* [2003] particularly well. Below CME speeds of ~700 km/s, transit times tend to be shorter than predicted, while they tend to be longer for faster CMEs. Furthermore, variations in the specific trajectory of the observing spacecraft relative to the shock-ejecta ensemble (for example, whether this passes near the nose or flank of the shock [e.g., *Cane et al.*, 1994]), as well as differences in solar wind conditions and the scale size of the ejecta (possibly larger for the faster, most energetic events), are among the factors that will contribute to a scatter in standoff distances/times that is not reflected by the well-defined relationship between shock standoff time and CME speed or transit time assumed in this model.

[8] We must also reject the conclusion of *Gopalswamy et al.* [2003] that the work of *Cane et al.* [2000] is erroneous because ejecta and shocked sheaths were not properly distinguished. This conclusion is based on their incorrect supposition that ejecta identification in *Cane et al.* [2000] predominantly relied on the use of cosmic ray signatures, and that these signatures were not always correctly interpreted (a similar claim is also made on page 29,213 of *Gopalswamy et al.* [2001]). We did not rely on cosmic ray signatures to identify ejecta in the *Cane et al.* [2000] study. Rather, as clearly stated in the paper (and also directly quoted by *Gopalswamy et al.* [2003]), we considered them along with other signatures, in particular those in the plasma and magnetic field data, when identifying ejecta and the associated shock or upstream "wave", if present. We are well aware of the intricacies of interpreting cosmic ray decreases as outlined by *Gopalswamy et al.* [2003] - we should point out that the first author of *Cane et al.* [2000] is also the author of an invited review paper on cosmic ray depressions caused by CMEs [*Cane*, 2000]. We did not discuss this topic in *Cane et al.* [2000] because cosmic ray decreases were not the primary method of identifying ejecta. Thus, the claim of *Gopalswamy et al.* [2003] that we unknowingly confused ejecta with shocked sheaths is false.

[9] Finally, we should note that details of the events used in the *Cane et al.* [2000] study (including disturbance and ejecta times), together with those for additional events in 1996–2002, are given in a recent paper [*Cane and Richardson*, 2003].

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